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Clarke

(54) **HYDRAULIC TRANSFORMER USING A PAIR OF VARIABLE DISPLACEMENT GEAR PUMPS**

(76) Inventor: **John M. Clarke**, Chillicothe, IL (US)

Correspondence Address:
Taylor & Aust, P.C.
ATTN: Todd T. Taylor
142 South Main Street
P.O. Box 560
Avilla, IN 46710 (US)

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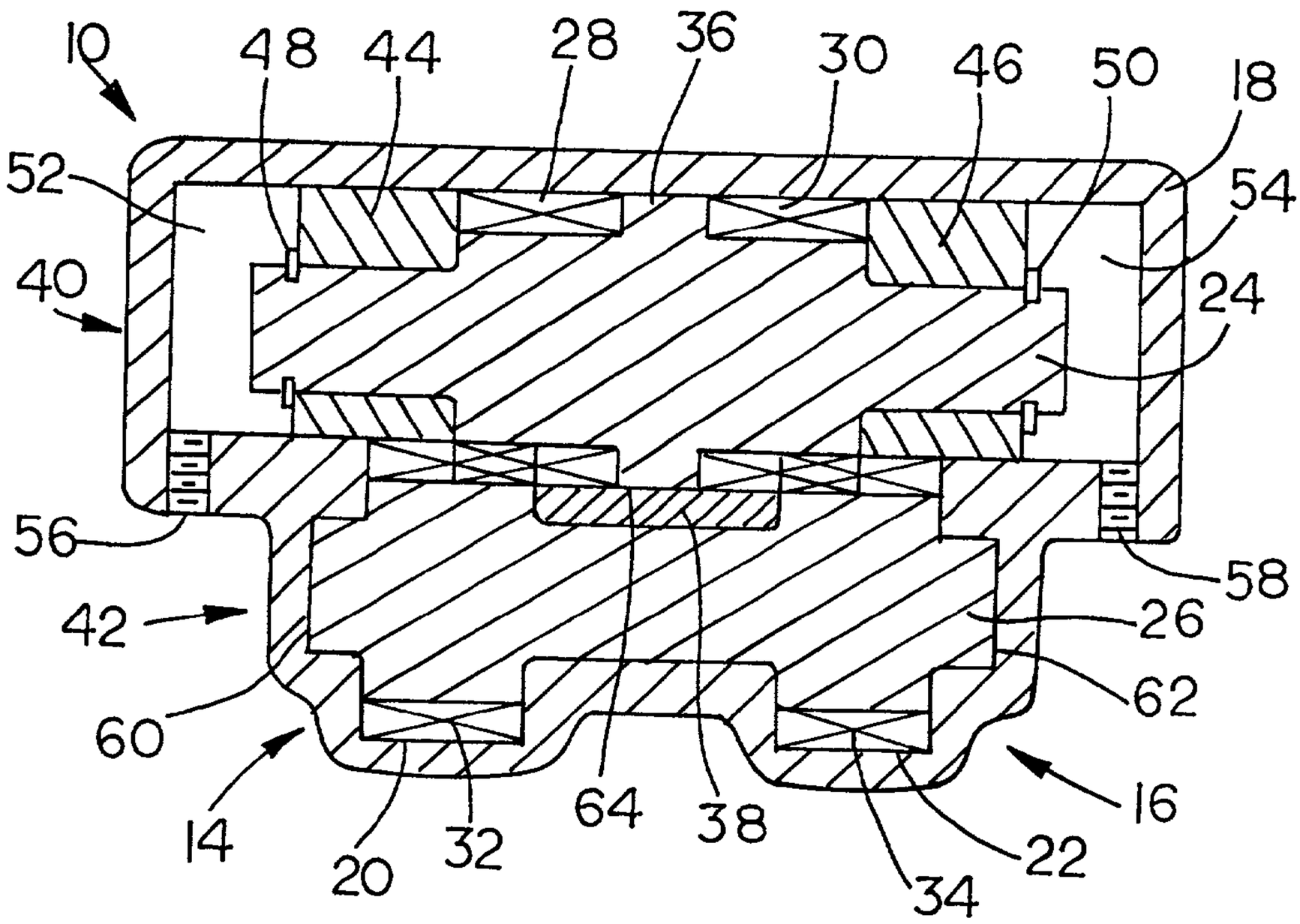
(57) **ABSTRACT**

A hydraulic transformer for controlling hydraulic fluid pressure and flow to a hydraulic device includes first and second variable flow rate gear pumps supplied with high-pressure hydraulic fluid and low-pressure hydraulic fluid such that the delivery pressure and flow can be controlled, as needed. First gears of the first and second gear pumps are disposed on a common first shaft, and second gears of the first and second gear pumps are disposed on a common second shaft. Relative axial movement between the first and second shafts causes increased or decreased engagement length between the first and second gears of both the first gear pump and the second gear pump.



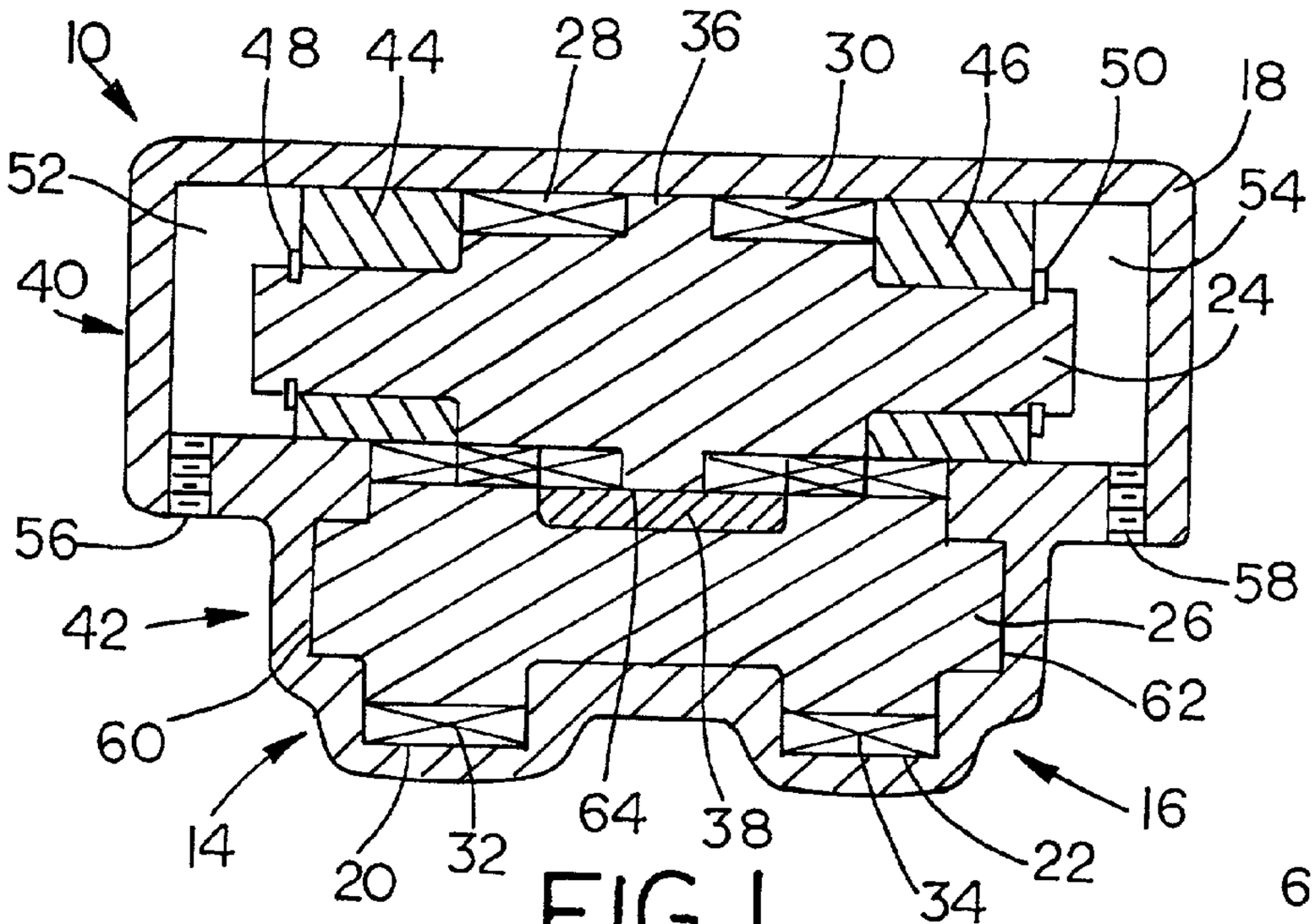


FIG. 1

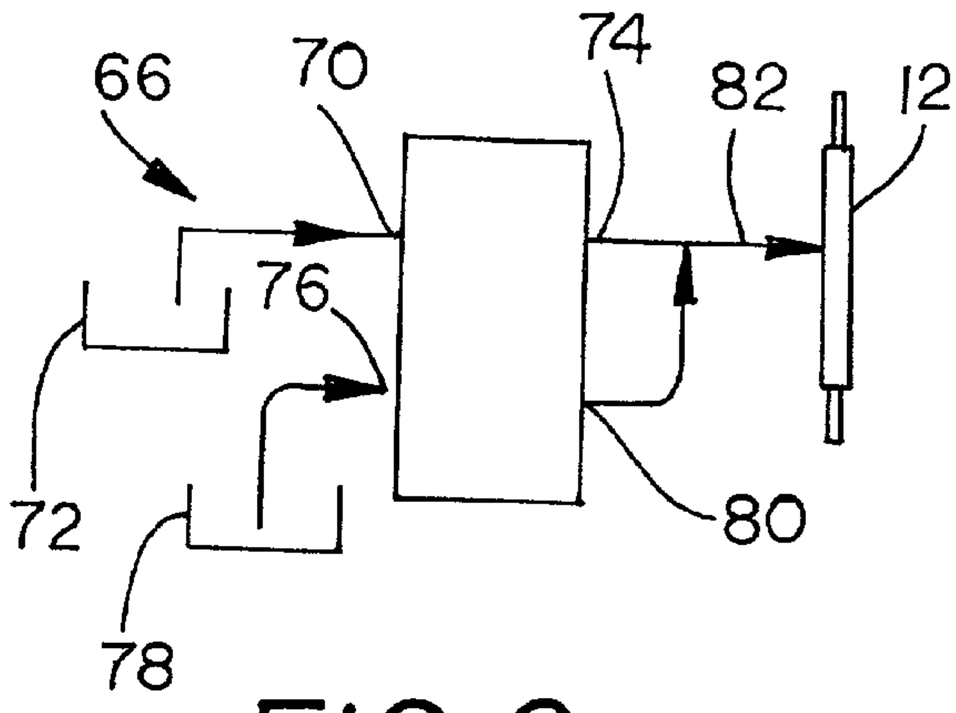


FIG. 2

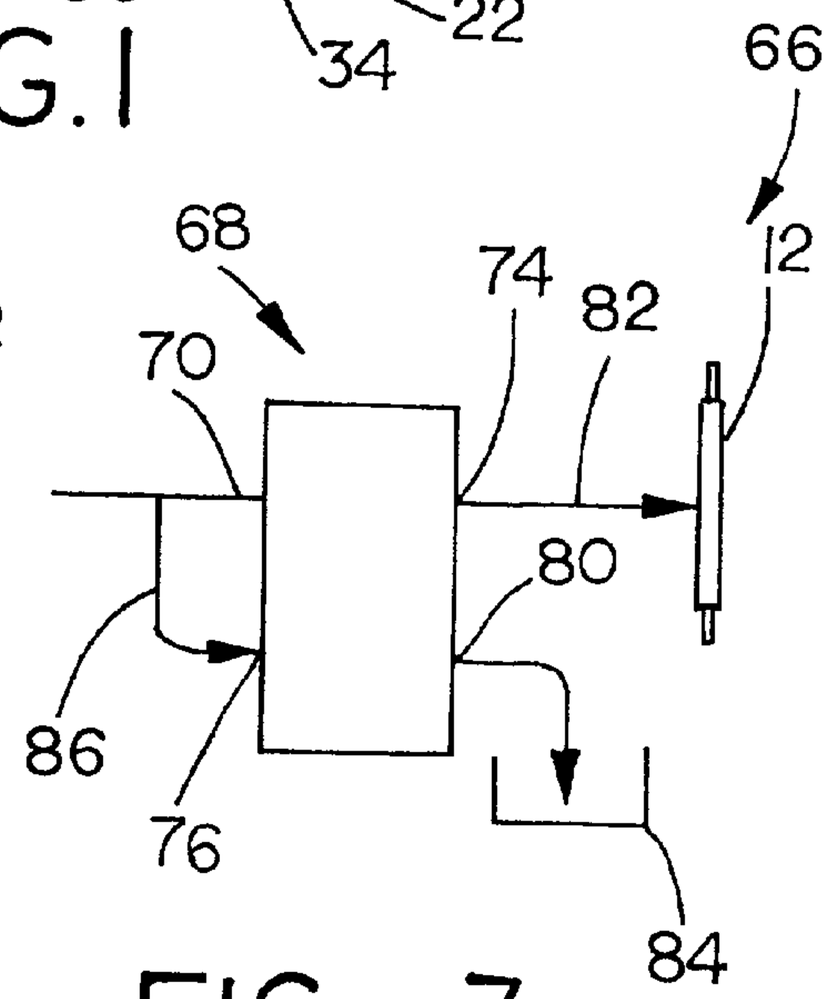


FIG. 3

HYDRAULIC TRANSFORMER USING A PAIR OF VARIABLE DISPLACEMENT GEAR PUMPS

TECHNICAL FIELD

[0001] The present invention relates to hydraulic systems and, more particularly, to hydraulic pressure transformers for hydraulic systems.

BACKGROUND ART

[0002] Work machines commonly use devices such as hydraulic motors and hydraulic pistons as drive and operating mechanisms. A pump may supply high-pressure fluid to the device. If the device, such as a hydraulic cylinder, is to be operated under low load, it is known to throttle the hydraulic line to lower the pressure of the hydraulic fluid supplied, thereby facilitating control and performance. Lowering the hydraulic fluid pressure by throttling the hydraulic line works well in operating the device, however, resistance created in the line to lower the pressure results in significant energy loss in the hydraulic system.

[0003] In some hydraulic systems, a transformer is necessary for the efficient use of hydraulic power to drive wheels or operate cylinders. When the hydraulic system includes a source of hydraulic fluid at a fixed delivery pressure from an accumulator or the like, the transformer can be used to convert the source pressure and flow into nearly equal deliver power having lower pressure and higher flow, or higher pressure and lower flow.

[0004] Known hydraulic pressure transformers include a rotatable port block having ports therein for selectively connecting the hydraulic fluid source with a hydraulic fluid delivery line. U.S. Pat. No. 6,092,455 entitled "Hydraulic Pressure Transformer" discloses a transformer of this general type. Such transformers are somewhat complex, and can be expensive to manufacture.

[0005] The present invention is directed to overcoming one or more of the problems as set forth above.

DISCLOSURE OF THE INVENTION

[0006] In one aspect of the invention, a hydraulic transformer comprises a variable displacement first gear pump connected to a high-pressure fluid source, and includes a cooperating gear couple having a variable engagement length. A variable displacement second gear pump is connected to a low-pressure fluid source, and includes a second cooperating gear couple having a variable engagement length.

[0007] In another aspect of the invention, a hydraulic system comprises a high-pressure fluid source, a low-pressure fluid source, and a transformer. The transformer has a variable displacement first pump connected to the high-pressure fluid source and a variable displacement second pump connected to the low-pressure fluid source. A delivery conduit is connected to receive flow from the variable displacement first pump and from the variable displacement second pump.

[0008] In yet another aspect of the invention, a method for providing hydraulic power comprises steps of providing a high-pressure fluid source and a low-pressure fluid source; providing a first gear pump connected to the high-pressure fluid source and a second gear pump connected to the low-pressure fluid source; providing a delivery line connected to receive fluid flow from the first gear pump and from the second gear pump; and adjusting the pumping performance of the first gear pump and the second gear pump to control flow rate and pressure of hydraulic fluid in the delivery line.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] **FIG. 1** is a cross-sectional view of a hydraulic transformer according to the present invention;

[0010] **FIG. 2** is a schematic representation of a hydraulic system having a hydraulic transformer of the present invention in one operating condition; and

[0011] **FIG. 3** is a schematic representation of a hydraulic system having a hydraulic transformer of the present invention in a second operating condition.

BEST MODE FOR CARRYING OUT THE INVENTION

[0012] Referring now to the drawings, and more particularly to **FIG. 1**, there is shown an embodiment of a hydraulic transformer **10** of the present invention. Hydraulic transformer **10** may be used in conjunction with a hydraulic motor, hydraulic piston or the like, collectively referred to herein as a hydraulic device **12**, shown in **FIG. 2**.

[0013] Hydraulic transformer **10** includes a first gear pump **14** and a second gear pump **16**. Each first gear pump **14** and second gear pump **16** comprises a variable displacement gear pump, as will be described in greater detail hereinafter.

[0014] First gear pump **14** and second gear pump **16** are disposed in a common housing **18**, which defines a first pumping chamber **20** for first gear pump **14** and a second pumping chamber **22** for second gear pump **16**. A first shaft **24** and a second shaft **26** are disposed in housing **18**. A first gear **28** of first gear pump **14** and a first gear **30** of second gear pump **16** are disposed on first shaft **24**. A second gear **32** of first gear pump **14** and a second gear **34** of second gear pump **16** are disposed on second shaft **26**. First gear **28** and second gear **32** of first gear pump **14** are operatively engaged to define a first gear couple disposed in first pumping chamber **20**. Gears **28** and **32** engage along a variable axial length, variation in the engagement length occurring from relative axial movement between the gears **28** and **32**. First gear **30** and second gear **34** of second gear pump **22** are operatively engaged to define a second gear couple disposed in second pumping chamber **22**. Gears **30** and **34** engage along a variable axial length, variation in the engagement length occurring from relative axial movement between the gears **30** and **34**.

[0015] First gears **28** and **30** of first gear pump **14** and second gear pump **16**, respectively, and second gears **32** and **34** of first gear pump **14** and second gear pump **16**, respectively, may be individual components disposed on first shaft **24** and second shaft **26**. Alternatively, gears **28**, **30**, **32** and/or **34** may be integral portions of first shaft **24** and second shaft **26** formed by casting, machining or other formation process. The tooth patterns for gears **28**, **30**, **32** and **34**, the number of teeth, configuration and the like may vary in different transformers **10**, as is known for common gear pump design.

[0016] First shaft **24** includes a collar **36** extending radially outwardly between first gear **28** and first gear **30** of first and second gear pumps **14** and **16**, respectively. Collar **36** may be integral with first shaft **24**, and extends outwardly at least as far as first gear **28** and first gear **30**.

[0017] Second shaft **26** defines a valley **38** between second gear **32** and second gear **34** of first gear pump **14** and second gear pump **16**, respectively.

[0018] Housing **18** defines a first shaft retaining zone **40** and a second shaft retaining zone **42**. First shaft **24** is mounted in sealing blocks **44** and **46** disposed at axially opposite ends of first shaft **24**, outwardly of first gears **28** and **30**, respectively. Sealing blocks **44** and **46** are disposed against outer surfaces of first gears **28** and **30**, and may be retained axially on first shaft **24** by locking rings **48** and **50**. Sealing blocks **44** and **46** are slidably carried in first shaft receiving zone **40**, and provide a hydraulic fluid seal against housing **18** at the perimeter of sealing blocks **44** and **46**. The assembly of first shaft **24**, first gears **28** and **30**, and sealing blocks **44** and **46** is axially slidable in first shaft retaining zone **40**. First shaft retaining zone **40** is sufficiently longer than first shaft **24** to define first and second pressure compartments **52** and **54** between the axially end portions of housing **18** and sealing blocks **44** and **46**, respectively. A first fluid port **56** is provided in housing **18** to establish fluid access to first pressure compartment **52**, and a second fluid port **58** is provided in housing **18** to establish fluid access to second pressure compartment **54**.

[0019] Second shaft retaining zone **42** defines shoulder areas **60** and **62** for receiving and retaining axially opposite ends of second shaft **26**. Second shaft **26** is rotatable but axially constrained in second shaft retaining zone **42**.

[0020] A seal **64** is disposed in housing **18**, between valley **38** and collar **36**. Valley **38** and collar **36** are rotatable against seal **64**, and against radially outer portions of housing **18**. The close associations of collar **36** with housing **18** and seal **64**, and of valley **38** with housing **18** and seal **64** provide pumping performance isolation of first gear pump **14** from second gear pump **16**.

[0021] Ports **56** and **58** are connected to a source of control pressure fluid, not shown, for supplying fluid to and accepting fluid from first pressure compartment **52** and second pressure compartment **54**. By pumping fluid into one of and removing fluid out of the other of first pressure compartment **52** and second pressure compartment **54**, first shaft **24**, together with sealing blocks **44** and **46** and first gears **28** and **30**, is caused to slide axially in first shaft retaining zone **40**.

[0022] First gears **28** and **30** of first and second gear pumps **14** and **16**, respectively, are disposed in housing **18** inwardly of second gears **32** and **34** of first and second gear pumps **14** and **16**, respectively. Thus, as first shaft **24** is caused to slide axially in first shaft retaining zone **40**, one of first gears **28** and **30** is caused to slide toward its mating second gear **32** or **34**, and the other of first gears **28** and **30** is caused to slide away from its mating second gear **32** or **34**.

[0023] **FIG. 2** and **FIG. 3** are schematic illustrations of hydraulic systems **66** and **68**, respectively, which utilize hydraulic transformers **10** of the present invention.

[0024] As shown for hydraulic system **66** in **FIG. 2**, first gear pump **14** has an inlet **70** connected to a high-pressure fluid source **72**. First gear pump **14** further includes an outlet **74**. Second gear pump **16** includes an inlet **76** connected to a low-pressure fluid source **78**. Second gear pump **16** further includes an outlet **80**. A delivery conduit **82** receives fluid from outlet **74** of first gear pump **14** and fluid from outlet **80** of second gear pump **16**. Delivery conduit **82** delivers hydraulic fluid to hydraulic device **12**.

[0025] Hydraulic system **68**, as shown in **FIG. 3**, includes hydraulic transformer **10** as described for hydraulic system **66** in **FIG. 2**, and further includes a fluid sump **84** (**FIG. 3**). Flow from high-pressure fluid source **72** may be diverted to inlet **76** of second gear pump **16** via a diversion conduit **86**.

[0026] Industrial Applicability

[0027] In use, hydraulic transformer **10** is provided in hydraulic system **66** or hydraulic system **68** for providing controlled flow of hydraulic fluid to hydraulic device **12**. Pumping performances of first gear pump **14** and second gear pump **16** can be altered simultaneously by axial movement of first shaft **24**. With respect to the view shown in **FIG. 1**, axial movement of first shaft **24** to the left causes an increased meshed area of first gear **28** and second gear **32** of first gear pump **14**. Simultaneously, first gear **30** is moved away from second gear **34**, decreasing the length of meshing for first gear **30** and second gear **34** of second gear pump **16**. Conversely, axial movement to the right causes a decrease in the length of meshing of first gear **28** and second gear **32** of first gear pump **14** and a simultaneous increase in meshed length between first gear **30** and second gear **34** of second gear pump **16**. Axial movement of first shaft **24** in first shaft retaining zone **40** can be effected by pumping a control fluid into or out of first pressure compartment **52** and second pressure compartment **54**, via first port **56** and second port **58**, respectively. Increasing the axial length of gear teeth meshing increases the pumping performance of either first gear pump **14** or second gear pump **16**. Decreasing the axial length of gear teeth meshing decreases the pumping performance of either first gear pump **14** or second gear pump **16**. Since the axial length of gear teeth meshing increases for one of gear pumps **14** and **16** as it decreases for the other, the pumping flow rate of one is increased as the pumping flow rate of the other is decreased.

[0028] To supply hydraulic fluid to hydraulic device **12** at a pressure less than the supply pressure available from high-pressure fluid source **72**, hydraulic transformer **10** is adjusted to decrease the pumping flow rate of first gear pump **14** and to increase the pumping flow rate of second gear pump **16**. Flow of high-pressure fluid to delivery conduit **82** is decreased, and flow of low-pressure fluid is increased. Thus, the delivery pressure at delivery conduit **82** will be less than the supply pressure available at inlet **70**, and the delivery flow, including the increased flow of low-pressure hydraulic fluid from low-pressure fluid source **78** will be greater than the supply flow available at inlet **70**. A system in which the delivery pressure is less than the high-pressure fluid supply pressure, and the delivery flow is greater than the supply flow of high-pressure fluid, is shown in **FIG. 2**.

[0029] **FIG. 3** illustrates schematically a system in which a higher delivery pressure is desired, with the delivery flow being less than the supply flow. In the illustration, a portion of the supply flow is diverted through diversion conduit **86** to sump **84** to provide the power to raise the pressure in the other flow.

[0030] Using hydraulic transformer **10** of the present invention, the hydraulic flow and pressure available at device **12** can be controlled as required. The transformer uses basic concepts of simple and reliable gear pump designs.

[0031] Other aspects, objects and advantages of this invention can be obtained from a study of the drawings, the disclosure and the appended claims.

1. A hydraulic transformer comprising:

a variable displacement first gear pump connected to a high-pressure fluid source and including a cooperating gear couple having a variable engagement length;

a variable displacement second gear pump connected to a low-pressure fluid source and including a second cooperating gear couple having a variable engagement length; and

a delivery conduit receiving fluid flow from said variable displacement first gear pump and from said variable displacement second gear pump.

2. The hydraulic transformer of claim 1 including a housing defining a first pumping chamber for said variable displacement first gear pump and a second pumping chamber for said variable displacement second gear pump.

3. The hydraulic transformer of claim 2, each said first cooperating gear couple and said second cooperating gear couple having an idler gear and a drive gear.

4. The hydraulic transformer of claim 2 having a first shaft and a second shaft disposed in said housing, said first shaft having a first gear of said first gear couple and a first gear of said second gear couple disposed thereon, and said second shaft having a second gear of said first gear couple and a second gear of said second gear couple disposed thereon.

5. The hydraulic transformer of claim 4, said first shaft and said second shaft being axially adjustable relative to each other.

6. The hydraulic transformer of claim 5, one of said shafts being axially constrained in said housing and the other said shafts being axially movable in said housing.

7. The hydraulic transformer of claim 6, said first gears being positioned inwardly of said second gears such that relative axial movement of said shafts decreases axial engagement between one said gear couple and increases axial engagement length between the other said gear couple.

8. The hydraulic transformer of claim 1 including a first shaft and a second shaft, said first shaft having a first gear of said first gear couple and a first gear of said second gear couple disposed thereon, and said second shaft having a second gear of said first gear couple and a second gear of said second gear couple disposed thereon.

9. The hydraulic transformer of claim 8, said first shaft and said second shaft being axially adjustable relative to each other.

10. The hydraulic transformer of claim 9, one of said shafts being axially fixed and the other of said shafts being axially movable.

11. The hydraulic transformer of claim 10, said first gears and said second gears being positioned on said first shaft and said second shaft relative to each other such that relative axial movement of said shafts decreases axial engagement between one said gear couple and increases axial engagement length between the other said gear couple.

12. A hydraulic system comprising:

a high-pressure fluid source;

a low-pressure fluid source;

a transformer having a variable displacement first pump connected to said high-pressure fluid source and a variable displacement second pump connected to said low-pressure fluid source;

a delivery conduit connected to receive flow from said variable displacement first pump and from said variable displacement second pump; and

a hydraulic device connected to said deliver line.

13. The hydraulic system of claim 12, each said variable displacement first pump and said variable displacement second pump being a gear pump having axially adjustable gear teeth engagement length.

14. The hydraulic system of claim 12, including a common housing for said variable displacement first pump and said variable displacement second pump.

15. The hydraulic system of claim 14, including a first shaft disposed in said housing; a first gear from each said variable displacement first pump and from said variable displacement second pump provided on said first shaft; a second shaft disposed in said housing; and a second gear from each said variable displacement first pump and from said variable displacement second pump provided on said second shaft.

16. The hydraulic system of claim 15, one of said first and second shafts being axially fixed and the other being movable axially.

17. The hydraulic system of claim 16, said housing defining a first pressure compartment and a second pressure compartment, and including ports for the flow of control pressure fluid in said first and second pressure compartments, for axially adjusting the position of at least one of said first shaft and said second shaft in said housing.

18. The hydraulic system of claim 17, said first gears on said first shaft being disposed inwardly of said second gears on said second shaft in said housing.

19. The hydraulic system of claim 18, having a hydraulic fluid sump receiving hydraulic fluid flow from said transformer.

20. A method for providing relatively constant hydraulic power to a hydraulic device requiring variable hydraulic fluid pressure supply, said method comprising the steps of:

providing a high-pressure fluid source and a low-pressure fluid source;

providing a first gear pump connected to said high-pressure fluid source and a second gear pump connected to said low-pressure fluid source;

providing a delivery conduit connected to receive fluid flow from said first gear pump and from said second gear pump; and

adjusting the pumping flow rate of said first gear pump and said second gear pump to control flow rate and pressure of hydraulic fluid in said delivery conduit.

21. The method of claim 20, including steps of:

providing a first shaft and a first gear of each said first gear pump and said second gear pump on said first shaft, and a second shaft and a second gear of each said first gear pump and said second gear pump on said second shaft; and

adjusting axially the relative positions of said first shaft and said second shaft.

22. The method of claim 21, said adjusting the pumping flow rate achieved by altering an engagement length of said first gear and said second gear of at least one of said first gear pump and said second gear pump.

23. The method of claim 21, said adjusting the pumping flow rate achieved by altering engagement lengths of said first gear and said second gear of each said first gear pump and said second gear pump.

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